1,174,641

PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in Voltage Regulators

We, ROBERT BOSCH GMBH. a German Company, of 4, Breitscheidstrasse, Stuttgart-W, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

The invention relates to a voltage regulator for a generator which can be driven at widely fluctuating speeds, such as a three-phase a.c. dynamo for a motor vehicle, in which excitation current is fed periodically to the field winding of the generator through a controllable semiconductor switch, such as a transistor, in a sequence which is dependent on the instantaneous value of the generator output voltage.

In the case of generators of this type, which are used primarily in motor vehicles, the transistor which is connected in series with the field winding must be fully conductive when starting the generator from rest to ensure self-excitation of the generator. The transistor only switches into the blocked state when the rated value of the generator output voltage is exceeded. This rated value will depend on the number of cells in the vehicle accumulator which is connected to the generator. If high quality electrical equipment, in particular tele-communication equipment, which is sensitive to excess voltages, is connected to this accumulator, special protective measures must be taken to ensure that the generator is fully de-energized if a fault occurs in the regulator which would cause the rated value of the generator output voltage to be exceeded. Measures of this kind also protect the battery against damage which it would undergo if it were charged for a relatively long period with an excessively high voltage.

The device to protect against excess voltage ought also to be designed in such a way that it leads to de-energizing of the generator if one of the connection cables to the battery or output terminals of the generator works loose during operation. In this way the protective device automatically monitors its own operation.

According to the present invention a voltage regulator for a generator capable of being driven at widely fluctuating speeds comprises an electrically controllable semi-conductor switch for periodically supplying an excitation current to the field winding of the generator in a sequence which is dependent on the instantaneous value of the generator output voltage, and an excess voltage safety device which includes a relay having a normally open contact in series with the controllable semi-conductor switch and having its operating coil connectible across the generator output voltage through a series resistance, switching transistor or a controllable rectifier connected in parallel with the coil of the relay and means for rendering said switching transistor or controllable rectifier conductive when the output voltage exceeds a predetermined maximum value.

The device to protect against excess voltage which comprises the relay and the electronic switch connected in parallel therewith should preferably be set to respond at a voltage which is about 5% higher than the rated generator voltage to be maintained by the regulator. Consequently the device will not respond to slight fluctuations in the generator output voltage and will remain without influence on the regulator itself, unless damage of the type mentioned earlier occurs. However since in the case of regulators fitted with transistors, the main transistor which is connected in series with the field winding is itself unable to return to the blocked state when a fault occurs in the regulator, which

[*Price 4s. 6d.*]

would lead to a generator output voltage far exceeding the rated value, the device to protect against excess voltage also serves to monitor correct operation of the regulator. With this protective device it is also possible to protect the lighting system, which is fed by the generator, against switch-off of the accumulator, which acts as a buffer, during operation of the generator, if, in accordance with a further preferred feature of the invention the resistance in series with the relay coil and the electronic switch together with the electrical equipment necessary for the internal combustion engine which drives the generator, are connected through a switch to the battery and to the generator, which in turn is connected to the battery, it being essential to bring this switch into its closed position for operation of the generator.

The invention will be further described, by way of example, with reference to the accompanying drawings, in which:—

Fig. 1 is a circuit diagram of a generator which is provided with a regulator constructed in accordance with the invention and an indicator lamp which shows visually whether the generator is delivering power and

Fig. 2 is a circuit diagram similar to Fig. 1, but in the case of which the regulator is designed differently and an indicator light is not provided.

In figure 1 a three phase generator is marked with the reference number 10; the generator has three phase windings 11 in star connection and a shunt field winding 12. The windings 11 are connected to the input of a three-phase bridge rectifier 13, which feeds a positive load current lead 14 and a negative load current lead 15, to which a battery is connected and to which further current consumers which are not illustrated may also be connected. In addition three separate rectifiers 17 are connected to the windings 11 to deliver the excitation current; their cathodes are connected to a second positive lead 18.

A regulator 21 with a p—n—p type power transistor 22 and a p—n—p type input transistor 23 serves to supply current periodically to the field winding 12 in a sequence which is dependent on the instantaneous value of the generator output voltage between the leads 15 and 18.

In addition to device 24 to protect against excess voltage between the leads 14 and 15 is provided and comprises a p—n—p type transistor 25 and a controllable rectifier 26 with thyratron characteristics.

The permissible maximum value of the voltage between the leads 14 and 15 is at least 5% higher than the rated voltage of the generator 10 which must be maintained by the regulator 21.

The power transistor 22 of the regulator 21 has an emitter which is connected to the second positive lead through an emitter resistor 27. Its collector is connected to the field winding 12 through a make-and-break contact 28 which is actuated by a relay 29, when a switch marked 32 is thrown and the coil of the relay 29 connected to the voltage from the battery 16 through this switch (the circuit is illustrated with the relay 29 energized). A capacitor 33 for spark quenching is connected in parallel with the make-and-break contact 28. The field winding 12 is connected by its other end to the negative lead 15. A quenching diode 34 is connected in parallel with this winding and prevents excess voltages from arising when the excitation current is switched on and off.

If the relay 29 is not energized, the make-and-break contact 28 is brought back to its other position by a return spring, represented by an arrow in the drawing; in this position it connects the collector of the transistor 22 to the negative lead 15 through a resistor 35. In this switch position, no more excitation current flows in the field winding 12, so that the voltage at the generator 10 drops to the residual voltage and an indicator light 36 comes on; this light is located between the leads 14 and 18 and receives current from the battery 16 in this switch position through the transistor 22 and the resistors 27, 35. The indicator light 36 serves as a warning signal to show that there is a fault in the regulator 21 or in the generator 10, and that the battery 10 is not being charged.

The base of the transistor 22 is connected through two diodes 37 arranged in series and a resistor 38 and through a capacitor 39 arranged in parallel with these three components, to the collector of the input transistor 23. This collector is connected to the lead 15 through a collector resistor 40.

The emitter of the transistor 23 is connected to the second positive lead 18 and its base is connected to the cathode of a zener diode 43, and through a resistor 44 to the lead 18. The anode of the zener diode 43 is connected to the tapping point 45 of a voltage divider which consists of three resistors 46, 47, 48 and is connected to the leads 15 and 18.

The regulator 21 functions as follows: as long as the voltage between the leads 15 and 18 does not reach the rated value (which can be set at the tapping point 45), the zener diode 43 is blocked, since its zener voltage which serves as the reference voltage is not yet reached. Consequently no voltage is supplied to the base of the transistor 23, so that it is not conductive and its collector potential is highly negative. Consequently the transistor 22 is controlled into the conductive state by a base current which flows through the resistor 38 and the diodes 37. Excitation current flows through the transistor 22 to the

field winding 12, so that the output voltage of generator 10 rises.

Once the voltage between the leads 15 and 18 reaches its rated value, the zener diode 43 becomes conductive, current is supplied to the base of the transistor 23 which becomes conductive; consequently the potential at the collector of the transistor is displaced in the positive sense. The transistor 22 is then blocked, so that the excitation current in the field winding 12 is interrupted. When the generator out put voltage falls the zener diode ceases to conduct the the excitation current is re-established.

If the transistor 22 becomes defective, a permanent conductive connection is usually established between its emitter and its collector so that excitation current flows continually and the output voltage of the generator 10 becomes too high. This may lead to damage to the connected current consumers, e.g. lamp bulbs may blow or the battery 16 may be overcharged.

A function of the device 24 to protect against excess voltage is to prevent this phenomenon. The device has a positive lead 51 which is connected directly to the lead 14 through the switch 32. All the other normal current consumers are also connected to positive lead 51, as represented by the output lead 53, e.g. in the case of a motor vehicle, the headlamps, the ignition system and the starter. In addition the following are also connected to the positive lead 51: the relay 29 through a series resistor 54, the emitter of the transistor 25, the base of the transistor 25 through a resistor 55, one pole of a capacitor 56, the other pole of which is connected to the anode of a zener diode 57 which is connected by its cathode to the base of the transistor 25, and one end of a voltage divider which consists of three resistors 58, 59, 60 and is connected by its other end to the lead 15. This voltage divider has a tapping point 63, which is connected to the anode of the zener diode.

The controllable rectifier 26 is connected in parallel with the coil of the relay 29, in such a way that the cathode of this rectifier is connected to the lead 15, to which its control electrode is also connected through a resistor 64 and a capacitor 65 arranged in parallel therewith. In addition this control electrode is connected through a resistor 66 to the collector of the transistor 25, which is connected in turn through a capacitor 67 and a diode 68 and a parallel resistor 69 in series with the capacitor, to the base of the transistor 25.

The device 24 to protect against excess voltage shown in Fig. 1 functions as follows: if the transistor 22 is defective and a permanently conductive connection is established between its emitter and its collector, excitation current flows permanently through the field winding 12, so that the voltage between the leads 14 and 15 rises to a value which is higher than the set rated value. If this voltage reaches a given value e.g. 110% of the rated voltage the zener diode 57 which is blocked at lower voltages becomes conductive. Base current is now able to flow in the transistor 25; this current makes the transistor conductive so that a positive voltage surge occurs at the junction between the resistors 64 and 66, to which negative potential from the lead 15 was applied when the transistor 25 was blocked, and is applied to the control electrode of the rectifier 26 to fire the latter. Since the rectifier 26 is connected in parallel with the relay 29, the latter is short-circuited and no longer receives energizing current, so that the make-and-break contact 28 is released and switches over, in the direction shown by the arrow, to the resistor 35. Current therefore ceases to flow in the field winding 12 and the voltage at the output of the generator drops almost to zero. At the same time the indicator lamp 36 comes on and gives a visual warning signal.

The circuit shown in Fig. 1 offers the advantage that once the device to protect against excess voltage has actuated, it remains effective until the switch 32 is opened and the electrical equipment switched off but that it then returns automatically to its normal condition in which the rectifier 26 is blocked.

Fig. 2 shows a circuit which is similar to that illustrated in Figure 1 but has no indicator lamp to indicate failure of the regulator or the dynamo.

As is the case in Fig. 1, Fig. 2 shows a three-phase generator 72, with three phase windings 73 in star connection which feed a positive load current lead 75 and a negative load current lead 76 through a three-phase bridge rectifier 74; a battery 78 and possibly also other current consumers (not illustrated) which are connected to these leads through a reverse-current cut-out diode 77. A contact 79 of a relay 80, which can only be switched on during actuation of the starter, is connected in parallel with the reverse-current cut-out diode 77. (The starter belongs to the internal combustion engine which is also not illustrated and drives the generator 73). A regulator 83, with an n—p—n type power transistor 84 and an n—p—n type input transistor 85, serves to supply current periodically to a shunt field winding 86 of the generator in a sequence which is dependent on the value of the generator output voltage between the leads 75 and 76. In addition a device 87 to protect against excess voltage is provided; this device contains an n—p—n type transistor 88 and a relay 89 with a normally open contact 90 and prevents the voltage between the leads 75 and 76 from rising above a maxi-

mum permissible value. A spark quenching capacitor 93 is connected in parallel with the contact 90. The contact 90 is closed as illustrated in Fig. 2 when current flows through the coil of the relay 89. A quenching diode 94, in parallel with the field winding 86, one end of which is connected to the contact 90 and the other to the lead 75, prevents excess voltage when the excitation current is switched on and off. The other point of the contact 90 is linked to the collector of the transistor 84, whose emitter is connected to the lead 76. Its base is connected, through a series arrangement of a diode 95 and a resistor 96 and through a capacitor 97 connected in parallel with this series arrangement, to the collector of the transistor 85, which is connected in turn to the lead 75 through a collector resistor 98. The emitter of the transistor 85 is connected to the lead 76, to which its base is also connected through a resistor 99. This base is also connected to the anode of a zener diode 100, whose cathode is connected to the tapping point 103 of a voltage divider which consists of three resistors 104, 105, 106 and is arranged between the leads 75 and 76.

The regulator 83 functions as follows: assume that the contact 90 is closed so that excitation current can flow through the field winding 86. As long as the voltage between the leads 75 and 76 lies below the set rated value, the zener diode 100 is blocked and no current flows at the base of transistor 85, so that this too is blocked. Consequently its collector is highly positive, so that the base of the transistor 84 also receives a positive potential through the resistor 96 and the diode 95; transistor 84 is therefore conductive i.e. excitation current flows.

Once the voltage between the leads 75 and 76 reaches the required rated value, the zener diode 100 becomes conductive, as does also the transistor 85, so that the transistor 84 is blocked and the excitation current is interrupted; the voltage between leads 75 and 76 therefore drops again until the zener diode 100 no longer conducts and the field current is re-established.

If the power transistor 84 becomes defective, a permanent conductive connection is usually established between its emitter and its collector so that excitation current flows continually and the voltage between the leads 75 and 76 becomes very high. In order to prevent this, the device 87 to protect against excess voltage is provided; when excess voltage occurs, this device reduces the output voltage of the generator 72 down to almost zero.

One end of the coil of the relay 89 is linked to the lead 76 and its other end to the lead 75 through a series resistor 107. A quenching diode 108 which prevents the occurrence of detrimetal voltage peaks is connected in parallel with the relay coil. When the generator 72 is started, the relay 89 is switched on since during the starting operation the relay 80 which is connected to the starter momentarily bridges the return-current cut-out diode 77 through its contact 79; consequently current flows from the battery 78 through the relay 89 and also, via the contact 90 which is now closed, through the field winding 86, so that the generator 72 can produce a voltage which holds the relay 89 closed when the contact 79 opens again on termination of the starting operation.

The emitter-collector path of the transistor 88 is connected in parallel with the coil of the relay 89; its collector is connected to the end of relay coil connected to the series resistor 107, and its emitter to the lead 76 via a compensation diode 109. A capacitor 112 is arranged between its base, which serves as the input, and its collector which serves as the output. In addition the base is connected to the lead 76 through a resistor 113, and also directly to the anode of a zener diode 114, the cathode of which is connected to a tapping point 115 or a voltage divider which consists of three resistors 116, 117, 118 and is connected to the leads 75 and 76. A capacitor 119 is arranged between the tapping point 115 and the lead 76.

The device 87 to protect against excess voltage functions as follows: if the power transistor 84 becomes defective and a permanently conductive connection is established between its emitter and its collector, excitation current can flow constantly through the field winding 86, so that the voltage between the leads 75 and 76 rises to a value which is higher than the set rated voltage. Once this voltage reaches a value of e.g. 110% of the rated voltage, the zener diode 114 which is blocked at lower voltages becomes conductive and current is able to flow at the base of the transistor 88, thus causing its emitter-collector path to become conductive. Consequently the relay 99 is shunted and no longer receives energizing current, so that the contact 99 is released and opens in the direction shown by the arrow. The field winding 86 therefore becomes free from current and the voltage at the output from the generator drops.

The capacitor 112 is provided in order to prevent the transistor 88 from becoming non-conductive again while the voltage drops thus enabling the relay 89 to switch on again. As soon as the transistor 88 becomes conductive, this capacitor is charged through the zener diode 114, in such a way that its right-hand pole becomes positive and its left-hand pole, which is connected to the lead 76 through the transistor 88, becomes negative. When the generator output voltage drops,

the zener diode 114 again becomes non-conductive and the transistor 88 tends to block again so that its collector potential rises in the positive direction once more. This positive potential is transmitted through the capacitor 113 to the base of this transistor, so that current still flows at the base and keeps the transistor in the conductive state. This ensures that the transistor 88 remains conductive long enough for the voltage at the generator 72 to drop to a value which is no longer sufficient to energize the relay 89. The device to protect against excess voltage 87 therefore switches the generator 72 off completely; only when the generator output voltage has fallen to a very low level, does the transistor 88 return to its non-conductive state. The circuit shown in Fig. 2 also offers the advantage that the protection device 87 returns automatically to its normal state when the equipment is switched off. It is therefore merely necessary to change the regulator 83 if a fault occurs in power transistor 84.

A warning signal can also be provided in the circuit shown in Fig. 2 e.g. a lamp which is connected to the battery 78 through a second contact of the relay 89, when the device 87 to protect against excess voltage responds.

WHAT WE CLAIM IS:—

1. A voltage regulator for a generator which can be driven at widely fluctuating speeds, comprising an electrically controllable semi-conductor switch for periodically supplying an excitation current to the field winding of the generator in a sequence which is dependent on the instantaneous value of the generator output voltage and an excess voltage safety device which includes a relay having a normally open contact in series with the controllable semi-conductor switch and having its operating coil connectible across the generator output voltage through a series resistance, a switching transistor or a controllable rectifier connected in parallel with the coil of the relay and means for rendering said switching transistor or controllable rectifier conductive when the output voltage exceeds a predetermined value.

2. A regulator as claimed in claim 1, in which the last-mentioned means is such that the switching transistor or the controllable rectifier becomes conductive at a generator output voltage which is at least 5% higher than the rated voltage of the generator which is to be maintained by the regulator.

3. A regulator as claimed in claim 1 or 2, in which a switch is provided whereby the excess voltage safety device can be connected to a battery at least when the generator is started.

4. A regulator as claimed in claim 3, in which said switch serves to connect the generator and the battery to said excess voltage safety device and to electrical equipment which is necessary for the operation of an internal combustion engine which drives the generator.

5. A regulator as claimed in any preceding claim, in which a controllable rectifier is connected in parallel with said relay coil and said means for rendering the controllable rectifier conductive comprises a transistor whose control electrode is connected through a zener diode to a tapping point of a voltage divider which is connected to the generator output voltage, the output of this transistor being connected to the control electrode of the controllable rectifier so that the latter becomes conductive when the zener diode is conductive.

6. A regulator as claimed in any preceding claim for a generator which is an alternator provided with a bridge rectifier circuit for rectifying the alternator output, in which at least one separate rectifier is provided for supplying the excitation current.

7. A regulator as claimed in any preceding claim, in which the normally open contact is part of make-and-break contacts whose normally closed contact is connected to a resistor.

8. A regulator as claimed in claims 6 and 7, in which a pilot lamp is connected between the separate rectifier and one side of the bridge rectifier circuit in such a way that the pilot lamp receives current through the normally closed contact of the relay and through the controllable semiconductor switch when the relay is not energized.

9. A regulator as claimed in any of claims 1 to 4, in which said relay coil is connected in parallel with a transistor whose control electrode is connected through a zener diode to a tapping point of a voltage divider which is connectible to the generator output voltage so that the relay is shunted and thereby de-energized when the zener diode is conductive.

10. A regulator as claimed in claim 5 or claim 9, in which a capacitor is arranged between the output electrode and the control electrode of the transistor of the safety device.

11. A voltage regulator constructed and adapted to operate substantially as herein described with reference to and as illustrated in Fig. 1 of the accompanying drawings.

12. A voltage regulator constructed and adapted to operate substantially as herein described with reference to and as illustrated in Fig. 2 of the accompanying drawings.

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1174641 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

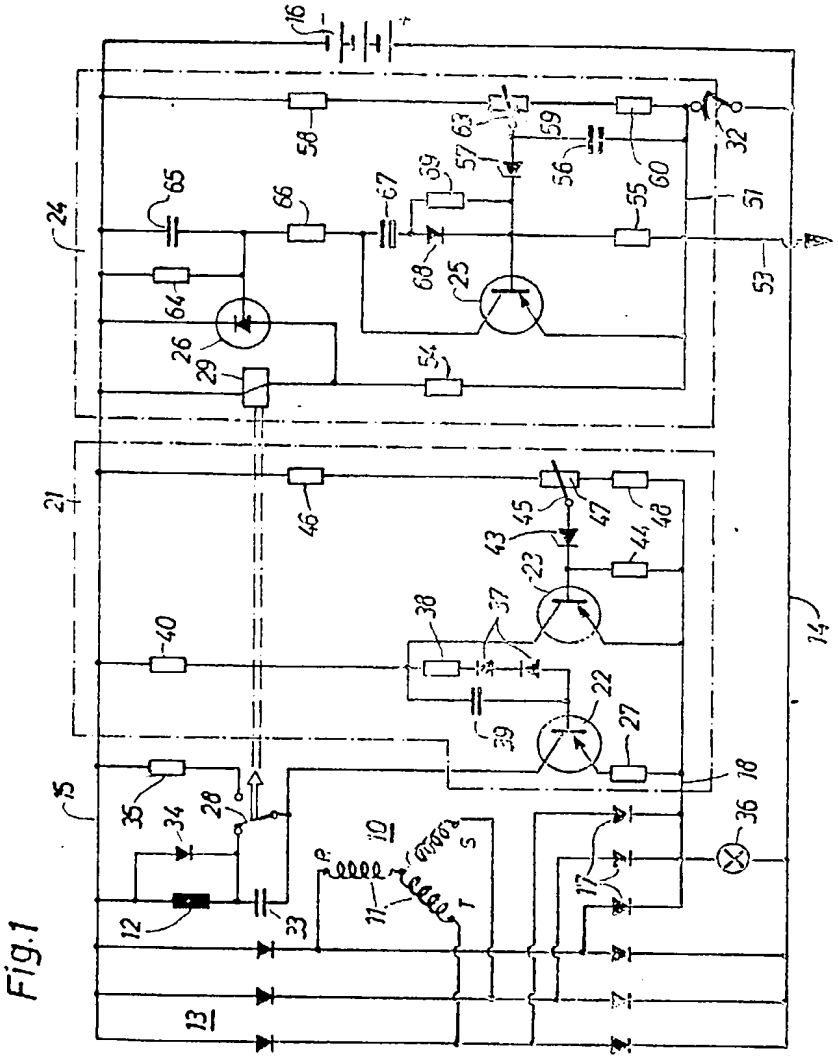

Fig.1

1174641 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

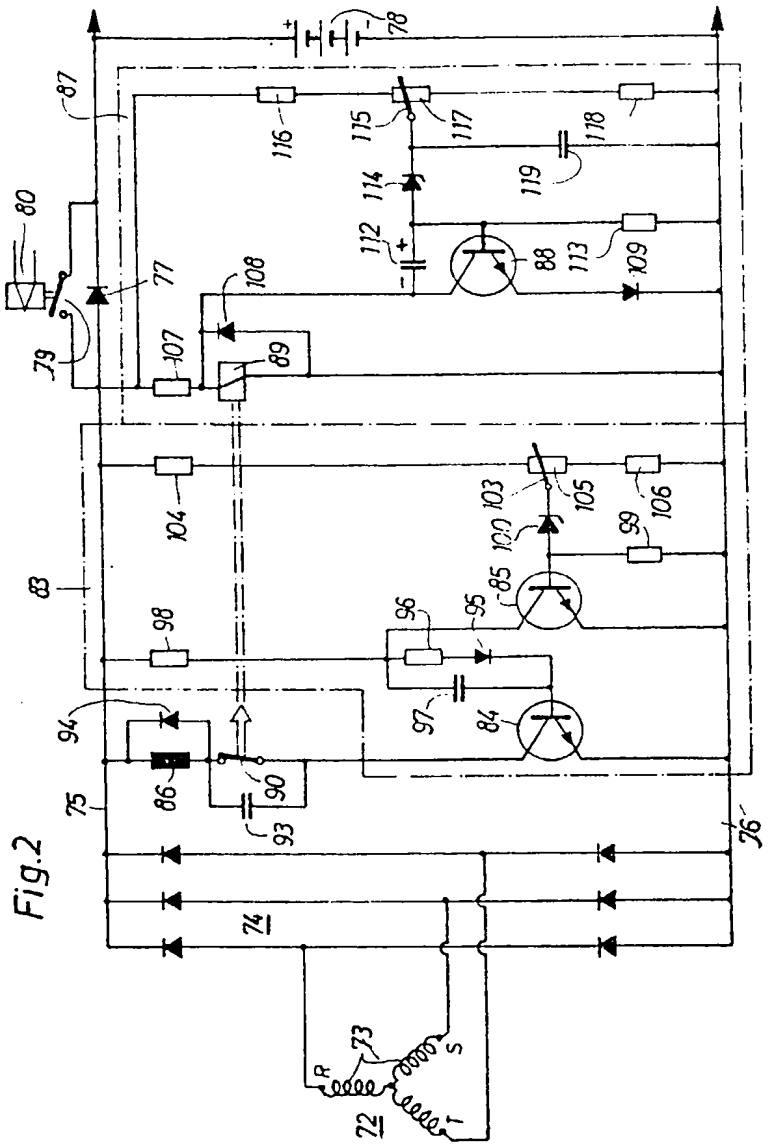

Fig.2